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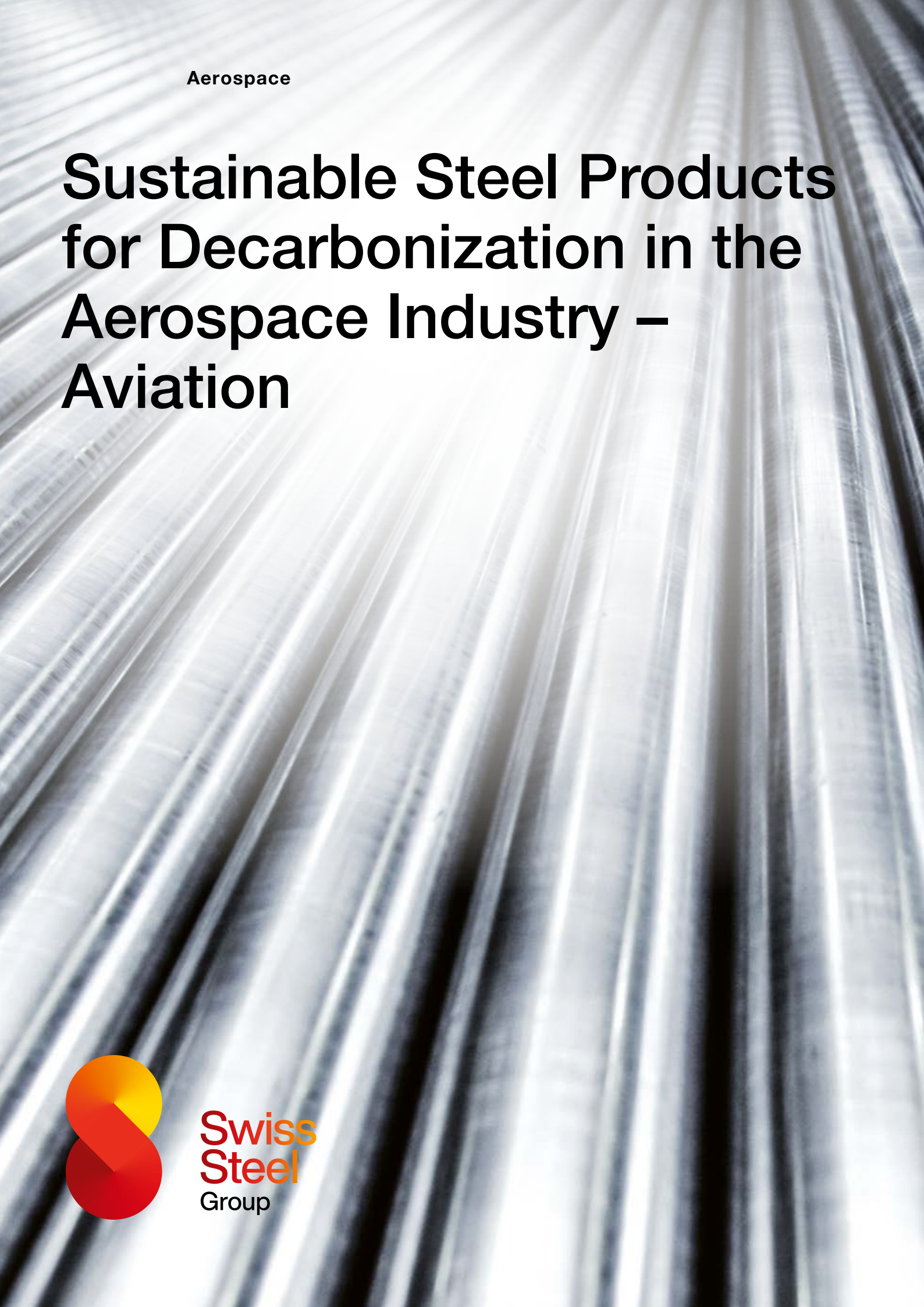
Sustainable Steel Products for Decarbonization in the Aerospace Industry – Aviation



Swiss Steel Group

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Introduction

The aerospace industry is faced with the challenge of meeting the net-zero emissions targets by 2050 to contribute decisively towards global climate protection efforts. Although the aviation industry accounts for only around four percent of the total greenhouse gas emissions in the EU, it is considered one of the sectors with the highest increase in greenhouse gas emissions that contribute to climate change. The main reason for this is the disproportionate increase in passenger numbers.

This calls for profound changes in all aspects of the aviation value-add chain, including the use of sustainable materials, alternative propulsion systems, more efficient engines, and the reduction of negative climate impacts while simultaneously achieving efficient, secure, and short supply chains. This White Paper examines the implications and potential solutions necessary to achieve these objectives, highlighting the crucial role of Swiss Steel Group in providing high-quality steel for sustainable aircraft designs.

Sustainability-related trends in the aerospace industry

The aviation industry is implementing various measures to reduce its impact on the environment and climate. These include:

1. More efficient propulsion systems

Every new generation of aircraft engine reduces fuel consumption by around twenty percent. Short and medium-range aircraft manufacturers are also testing electric and hydrogen-powered planes.

2. Sustainable fuels

Sustainable Aviation Fuels (SAF) is the generic term for all aviation fuels manufactured without using fossil energy sources. Compared to traditional fossil fuels, SAFs can reduce CO_2 emissions by eighty percent. They play a vital role in reducing non-CO_2 effects that contribute to climate change, such as vapor trails, soot, and aerosols. These emissions account for about two-thirds of the negative impact of aviation on the climate.

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3. Lightweight construction

Aircraft manufacturers are using lighter, stronger materials to reduce weight and fuel consumption. This development includes steel.

4. Recyclability and avoiding materials harmful to the environment

In order to minimize the impact of aviation on the environment throughout the entire lifespan of an airplane, it is necessary to use materials that can be recycled and reused, without causing harm to the environment. Any materials that are classified as “toxic” will no longer be allowed in the construction process.

5. Increase in air traffic and aircraft construction

Asia’s increasing prosperity is expected to result in a significant rise in air traffic. Already in 2016, the IATA forecast a doubling in passenger numbers by 2035. This situation will be further intensified, according to the most recent estimates, by the fact that 40,000 aircraft worldwide will need to be replaced between 2035 and 2050 due to sustainability concerns. This is equivalent today to an economic value of around five billion Euros[1]. This fact further intensifies the significance of aspects 1 and 2. This also means that production capacities for certain raw materials, and particularly for steels and titanium, need to be ramped up considerably. In addition, adequate qualification programs for production paths and products must also be implemented.

[1] Source: clean-aviation.eu

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The role of steel in aviation

Owing to its many different properties, aviation without steel is inconceivable. Steel is becoming increasingly important not only in terms of quantity but also for its unique applications. It is found in everything from standard components to highly critical parts such as landing gear, engine components, and parts and assemblies that are subjected to high mechanical loads. The aerospace industry uses fifty to one hundred different steel grades, which require a high degree of complexity and expertise in procurement of steel components. Although lighter weight materials are being explored, special steels remain indispensable for ensuring the required strength and safety of aviation applications.

The challenges steel faces

More efficient propulsion systems and alternative fuels

The engines of the future are designed with various characteristics to improve efficiency, performance, and reduce fuel consumption.

The most important characteristics are

1. **Higher efficiency:** New engine designs make use of advanced technologies, such as improved fluid mechanics, aerodynamic optimizations, and lower-density materials to achieve greater efficiency. This means that more thrust is produced while consuming less fuel.

2. **Lightweight construction:** Aircraft engines can be made lighter by using lighter weight materials such as carbon fiber composites and newly developed steels. This can significantly reduce the overall weight of the aircraft. To save more weight, higher strength steels are required to produce smaller components. The demand for steel in aviation is also increasing due to additive manufacturing. Current research is looking at manufacturing steel grades for use in aviation by means of Wire Arc Additive Manufacturing (WAAM). This means more complex, lighter weight geometries can be produced which cannot be manufactured using cutting or forging methods. The weight reductions achieved logically result in a lower overall aircraft weight and thus lower fuel consumption.

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3. **Ultramodern control systems:** Advanced control systems and sensor technologies make engine performance control more precise and adaptable to different flight conditions. This produces more efficient combustion and power delivery.

4. **Fan with larger diameter:** By increasing the diameter of the fan, engines can take in more air and thus produce more thrust without significantly increasing fuel consumption.

5. **New combustion chamber design:** State-of-the-art combustion chamber designs make fuel combustion more efficient which improves performance and lowers fuel consumption.

6. **Fuels of the future:** Switching from fossil kerosine to SAFs will make virtually CO_2 neutral aviation possible in the future. Aircraft can already be fueled with SAFs today, but it is still not readily available.

7. **Optimized propulsion systems:** The aim of these characteristics is to enhance the effectiveness and efficiency of jet engines, making air traffic eco-friendlier and more sustainable by reducing fuel consumption and emissions. To implement these characteristics new and known steels must meet the new mechanical demands and conditions for certification.

   In order to bring about these changes, the hydrogen infrastructure must be significantly expanded in regard to production, transport, storage, and combustion. For this purpose, due to safety concerns, steel grades are needed that are primarily also resistant to hydrogen embrittlement under high pressure and are unaffected by hydrogen's higher combustion temperature. This is crucial not just in the aerospace industry, but also in the chemical and steel sectors.

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8. **Recyclability and avoiding environmentally harmful materials:** Steel is a highly recyclable material that can be used repeatedly. When it comes to aircraft landing gear and components, steel is the preferred material due to its ability to withstand heavy loads and harsh environments. However, to make steel resistant to corrosive substances, coatings are often applied to it. Unfortunately, these coatings are often made from harmful substances such as cadmium, chromium (VI) compounds, or zinc-nickel, which makes recycling difficult and sometimes impossible. As a result, these harmful substances need to be disposed of responsibly to avoid environmental and health risks. European environmental regulations like REACH[2] mandate the safe disposal of these materials. To comply with these regulations and encourage sustainability, new steel coatings that do not contain these harmful substances are needed.

9. **Increase in air traffic and aircraft construction:** To meet the future demand for steel in the aviation industry, scalable production processes with high process stability are needed. This is especially important to meet the high quality standards in aviation and to produce the required steel microstructures reliably and with short lead times without increasing scrap rates.

[2] REACH: Registration, Evaluation, Authorisation and Restriction of Chemicals

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Specific solutions

1. More efficient propulsion systems and alternative fuels

Stainless steel grades, such as 1.4435 or 1.4636 possess ductility even at pressures of over one hundred bar which meets the safety requirements for the storage of hydrogen. Stainless, high-strength austenitic grades such as XM-19 (1.3964 Mod or 1.4681) or Magnadur 601 are options for hydrogen valves or injectors. Special steel manufacturers like Swiss Steel Group are leading the way in the development of austenitic grades resistant to hydrogen embrittlement.

2. Lightweight construction

Manufacturers are currently already researching the use of WAAM[3] to apply known steel grades to massive components. This is done by layering steel to produce complex, lighter structures on a component surface. This method not only reduces weight but also lowers manufacturing costs.

3. Recyclability and avoidance of environmentally harmful materials

As an alternative to high-strength heat-treated steels that require cadmium or ZnNi coating for the corrosive aviation environment, a high-strength stainless Maraging[4] steel could potentially be used in the future. This steel has comparable material properties and the advantage of not needing any coating due to the alloy layer. This makes the steel fully recyclable, resulting in low lifecycle costs. However, until then, research must continue to take all types of steels from lab setups to large-scale industrial production processes. This presents significant challenges regarding suitable large-scale remelting processes and heat treatments that significantly influence steel properties.

The use of these types of steels and avoiding of special layers thus makes a considerable difference in improving sustainability by means of recycling in the aviation sector which in the past has relied heavily on non-recyclable materials like carbon composites.

[3] Wire Arc Additive Manufacturing
[4] Martensite + Aging: martensitaushärtbar

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4. Increase in air traffic and aircraft construction

To ensure that steel production remains profitable and scalable from melting to casting, shaping and heat treatment, it requires seamless process monitoring and control. In aerospace applications, the demands on properties, traceability, and tracking are so high that a separate quality management and accreditation standard called NADCAP[5] was developed for the aerospace industry. Steel producers with NADCAP accreditation demonstrate that their highly specialized processes are robust and able to deliver the required quality repeatedly. One such process is heat treatment, which finely calibrates steel properties and is essential for its use in aerospace applications.

Steel producers are currently facing a significant dilemma that should not be underestimated.

1. On the one hand, they must keep pace with the increasing demand from the aerospace sector for production capacities, for steels like 300M, for example, that are commonly used in landing gear.

2. On the other hand, they face and must undergo rigorous accreditation processes, like NADCAP.

3. They must work on process and product qualification programs in tandem with OEMs and Tier 1 suppliers.

[5] NADCAP: National Aerospace and Defence Contractors Accreditation Program

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To accomplish this, a cross-functional efficient organization is needed.

- The duration and scope of commercial contracts are impacted by the OEM and Tier 1 order book scales over a period of 9 years.

- To establish long-term contracts and partnerships, a foundation of trust between steel producers and customers is crucial. This trust is built upon technical expertise, stringent monitoring, and traceability that align with the customer's requirements and quality standards.

- To improve the properties of steel, many producers use simulation tools to predict microstructure properties.

- In order to build trust with business partners and engage in long-term, costly joint research and development processes, it is necessary to digitize and automate material testing. The combination of quality, reliability, profitability, and speed is ultimately decisive in achieving this goal.

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The role of Swiss Steel Group

Swiss Steel Group delivers high-quality steel that meets the demanding requirements of the aviation industry whether in wing actuators, landing gear, or engines.

Innovations, adaptability, and sustainability mark the future of steel in the aerospace industry.

Companies like Swiss Steel Group play a decisive role in supplying high-quality steels that meet the demands of the future. This requires stringent monitoring of suppliers. Customers in the aerospace and aviation industries require AS 9100, AS 9120 and NADCAP accreditation, for example. Together, Ugitech and Deutsche Edelstahlwerke, both Swiss Steel Group companies, have the following certifications:

- ISO 9001 (Quality Management System)
- ISO 14001 (Environment Management System)
- ISO 50001 (Energy Management System)
- AS 9100 (Aerospace Manufacturers)
- AS 9120 (Quality Management Systems-Aerospace Requirements for Stockist Distributors)
- NADCAP (Heat Treatment, Ultrasound)
- ISO 17025 (Test Laboratory)

Deliveries for the aviation industry often also require additional, custom customer approvals and the exchange with highly qualified production and quality teams, frequently consisting of metallurgic experts who optimally understand steel production processes and have sometimes even designed them. Swiss Steel Group companies are in the process of approving various Tier 1 contractors and suppliers because they have proven their ability to implement flexible process improvements and are in close exchange with expert teams on the customer's side. When it comes to sustainability, Swiss Steel Group has a CDP rating of "B" that guarantees that the requirements on the customer side are also met in this regard.

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Conclusion

The decarbonization of the aerospace industry is a top priority in order to meet climate targets. CO_2 emissions are to be reduced by at least fifty-five percent across the EU by 2030 and by at least ninety percent by 2040 compared to 1990 levels. Climate neutrality is to be achieved by 2050.

Swiss Steel Group plays an important role in supplying high-quality steels for sustainable aircraft designs and construction and contributes to the development of more efficient propulsion systems and technologies that are even more environmentally friendly. The future of aviation depends on innovative and sustainable solutions, and Swiss Steel Group is an important player in this development.

Swiss Steel Group with headquarters in Lucerne (Switzerland) is one of the world's leading producers of special long steel products. Thanks to the exclusive use of steel scrap in electric arc furnaces, the Group is one of the most relevant companies in the circular economy in Europe and is among the market leaders in the segment of sustainably produced steel – Green Steel. Swiss Steel Group has their own production and distribution companies in over twenty-five countries and, in addition to a strong local presence, offers a wide range of custom solutions in engineering steel, stainless steel, and tool steel. Swiss Steel Group is listed on the SIX Swiss Exchange, reached 3.2bn EUR in sales in 2023, and has a workforce of 8,800.

www.swisssteel-group.com

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